1V

[redacted]

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

TECHNICAL MEMORANDUM X-634

STATIC LONGITUDINAL AND LATERAL AERODYNAMIC CHARACTERISTICS AT A MACH NUMBER OF 2.01 OF A TAILLESS DELTA V/STOL CONFIGURATION HAVING VARIABLE-SWEEP WING PANELS*

By M. Leroy Spearman and Gerald V. Foster

L
1
9
8
8

SUMMARY

21585

An investigation has been conducted in the Langley 4- by 4-foot supersonic pressure tunnel at a Mach number of 2.01 to determine the longitudinal and lateral aerodynamic characteristics of a tailless delta V/STOL configuration having variable-sweep wing panels and twin inlets.

The results of the investigation indicated that the inlet and duct arrangement had a large detrimental effect on both the longitudinal and the directional stability characteristics of the configuration. The longitudinal stability was improved by reducing the sweep and increasing the span of the delta planform wing whereas the directional stability was improved through the use of an enlarged vertical tail.

INTRODUCTION

author

The National Aeronautics and Space Administration is currently conducting studies directed toward the development of multimission airplanes wherein variable wing sweep is employed as a means of combining efficient subsonic and supersonic flight characteristics. Recent studies have also indicated the feasibility of employing vectored lift-thrust engines in such airplanes in order to provide the added capability of extremely short or vertical take-off. The results of some of the previous investigations of such airplanes are presented in references 1 to 5. These investigations have included tail-rearward airplanes with variable wing sweep and one with a rotatable or skewed wing.

This paper extends the study of such airplanes to include a configuration in which the fully retracted wing position provides a tailless

---

*Title, Unclassified.

[redacted]

[redacted]

airplane with a low-aspect-ratio delta wing. The model investigated had twin inlets and a four-nozzle exit arrangement similar to that used in some of the previous investigations. The investigation was made in the Langley 4- by 4-foot supersonic pressure tunnel at a Mach number of 2.01 and includes both the longitudinal and the lateral aerodynamic characteristics for various configuration arrangements. Transonic results for some of the configurations are presented in reference 6.

SYMBOLS

The results are referred to the body axis system except the lift and drag coefficients which are referred to the stability axis system. The moment reference points are shown in figure 1.

C_L lift coefficient, $\frac{\text{Lift}}{qS}$

C_D drag coefficient, $\frac{\text{Drag}}{qS}$

C_m pitching-moment coefficient, $\frac{\text{Pitching moment}}{qSc}$

C_l rolling-moment coefficient, $\frac{\text{Rolling moment}}{qSb}$

C_n yawing-moment coefficient, $\frac{\text{Yawing moment}}{qSb}$

C_Y side-force coefficient, $\frac{\text{Side force}}{qS}$

q free-stream dynamic pressure, lb/sq ft

S wing area including fuselage intercept for retracted 81° wing configuration, 0.76 sq ft

c reference length represented by distance from inlet leading edge to theoretical trailing-edge apex of winglet, 1.85 ft

b span of winglet neglecting control-surface tip, 0.679 ft

[redacted]

DECLASSIFIED

α angle of attack, deg

β angle of sideslip, deg

δ_h pitch-control-surface deflection, deg

Λ sweep angle of wing leading edge, deg

L/D lift-drag ratio, C_L/C_D

L1988

C_{n_β} directional-stability parameter, $\frac{\partial C_n}{\partial \beta}$

C_{l_β} effective-dihedral parameter, $\frac{\partial C_l}{\partial \beta}$

C_{Y_β} side-force parameter, $\frac{\partial C_Y}{\partial \beta}$

TESTS, CORRECTIONS, AND ACCURACY

The test conditions are as follows:

Mach number	2.01
Stagnation temperature, $^\circ$F	100
Stagnation pressure:	
For longitudinal tests, lb/sq ft	1,440
For lateral tests, lb/sq ft	720
Reynolds number, based on $\bar{c}$:	
For longitudinal tests	4.07×10^6
For lateral tests	2.04×10^6

The stagnation dewpoint was maintained sufficiently low (-25° F or less) so that no condensation effects were encountered in the test section.

Transition strips were located near the nose and inlet tips, and near the leading edges of the vertical tail and pitch-control tip.

The angles of attack and sideslip were corrected for the deflection of the balance and sting under load. The base pressure was measured, and the drag force was adjusted to a base pressure equal to free-stream static pressure. Where applicable, the drag results have also been

[redacted]

corrected to account for the internal drag of the ducts. Schlieren photographs of the inlets indicated that some spillage was occurring.

The estimated accuracy of the individual measured quantities is as follows:

C_L	±0.0039
C_D	±0.0004
C_m	±0.0006
C_l	±0.0003
C_n	±0.0015
C_Y	±0.0032
α, deg	±0.1
β, deg	±0.1
δ_h, deg	±0.1

MODELS AND APPARATUS

Details of the models are shown in figure 1. The models were constructed in such a way that the ducts could be removed entirely or replaced by solid ducts. The wing assembly was composed of three parts - a fixed portion referred to as the winglet, movable wing panels that could be rotated to provide a sweep range from 15° to fully retracted, and the pitch-control surfaces at the rear of the winglet that could be deflected to various angles or removed altogether. The original configuration was investigated with both an 81° swept winglet and a 73° swept winglet. The revised configuration (fig. 1(b)) differed from the original configuration in that a longer, higher fineness-ratio forebody was incorporated, the winglet provided a fully retracted sweep angle of 71.75°, and the pitch-control tip was modified to provide a pointed tip. Vertical-tail modifications included a twin-tail arrangement for the original configuration with the 73° winglet wherein twin tails having a total area equal to that for the single tail were located near the wing tips. In addition, a large tail having a 20-percent increase in area was investigated on the revised configuration.

Tests were also made with various components removed and with various modifications to the ducts and winglet. These components and modifications are denoted as follows:

A solid chin-type duct

B winglet apex removed at point of intersection with body

C solid twin duct and control-tip dihedral of -5°

D solid twin duct and control-tip dihedral of -25°

[redacted]

E winglet leading-edge cutback to have sweep of 41° and to intersect original leading edge just ahead of wing pivot location

H pitch-control surface

V vertical tail

The model was mounted in the tunnel on a remote-controlled sting, and force measurements were made through the use of a six-component internal strain-gage balance.

PRESENTATION OF RESULTS

The results of the investigation and the figures in which they are found are shown in the following table:

[redacted]

[redacted]

DISCUSSION

Longitudinal Characteristics

The results for the complete model of the original configuration indicate a low level of longitudinal stability and a nonlinear variation of C_m with C_L that leads to pitch-up at higher lifts (fig. 2(a)). These results are apparently influenced by an interference of the inlet and duct flow fields on the wing since removal of the ducts eliminates the detrimental effects on the longitudinal stability (fig. 2(a)). L1988 Although several modifications to the ducts and the winglet apex were investigated (fig. 3), none of the changes eliminated the nonlinear pitching-moment characteristics. The sensitivity of the configuration to the forebody flow field is indicated by the results of figure 4 wherein the addition of a very-small-span strake to the forebody of the model with the ducts removed produced a measurable difference in pitching-moment characteristics. Varying the wing sweep for the original configuration from the fully retracted position of 81° to positions of 70° and 60° resulted in a marked improvement in the longitudinal stability (fig. 5(a)) as well as an increase in the maximum value of L/D (fig. 5(b)). On the basis of these results the original configuration was modified to incorporate a wing with the span increased and the sweep reduced to 73°. A comparison of results for the configuration with the modified wing planform with those for the original configuration indicates a considerable improvement in longitudinal stability and in the performance characteristics for the modified wing planform (fig. 6). A limited investigation of the pitch-control characteristics for the configuration having the wing planform modification (fig. 7) indicates relatively low controllability inasmuch as a control deflection of -10° appears to be about half that required to trim at the lift required for maximum L/D. The controllability is restricted to some extent by the negative value of C_m that exists at zero lift for the configuration with undeflected controls.

Limited tests were also made for a revised configuration having an increased forebody length and a 71.75° sweep delta planform. The results for this configuration (fig. 8) indicate that, although the detrimental effects of the duct on longitudinal stability are still present, the complete configuration was stable up to a lift coefficient of about 0.3, above which essentially neutral stability occurred.

Lateral Characteristics

The sideslip derivatives for the original configuration with the vertical tail on indicate neutral directional stability at $\alpha = 0^\circ$

[redacted]

(fig. 9(a)). Although a substantial tail contribution to C_{n_β} is apparent, the unstable moment of the tail-off configuration is so great that the addition of the tail is not sufficient to provide stability. A portion of the unstable moment is caused by the ducts so that when the ducts are removed the tail is able to provide positive directional stability up to about $\alpha = 5^{\circ}$ (figs. 9(b) and 10). With increasing angle of attack, the directional stability decreases rapidly with the ducts either on or off because of a loss in tail contribution that probably results from the effects of an adverse sidewash field produced by the forebody. The sideslip characteristics for the configuration having the modified wing planform are generally similar to those for the original configuration (figs. 11 and 12).

A twin-tail arrangement was investigated in an effort to locate the tail in a region of favorable sidewash. Although the variation of C_{n_β} with α at high angles of attack indicates that the twin tails are in a favorable sidewash field (fig. 13), the overwhelming influence of the unstable tail-off arrangement still indicates that an increase in tail area is required.

Both the original small tail and a large tail were investigated on the revised configuration. The results (fig. 14) indicate that with the small tail the configuration is even more unstable than the original configuration because of the added forebody length. However, with a 20-percent increase in tail area the configuration with the large tail provided positive C_{n_β} up to about $\alpha = 15^{\circ}$.

CONCLUDING REMARKS

An investigation has been conducted in the Langley 4- by 4-foot supersonic pressure tunnel at a Mach number of 2.01 to determine the longitudinal and lateral aerodynamic characteristics of a tailless delta V/STOL configuration having variable-sweep wing panels and twin inlets.

The results of the investigation indicated that the inlet and duct arrangement had a large detrimental effect on both the longitudinal and the directional stability characteristics of the configuration. The longitudinal stability was improved by reducing the sweep and increasing the span of the delta planform wing whereas the directional stability was improved through the use of an enlarged vertical tail.

Langley Research Center,
National Aeronautics and Space Administration,
Langley Air Force Base, Va., December 6, 1961.

[redacted]

[redacted]

REFERENCES

1. Luoma, Arvo A., and Alford, William J., Jr.: Performance, Stability, and Control Characteristics at Transonic Speeds of Three V/STOL Airplane Configurations With Wings of Variable Sweep. NASA TM X-321, 1960.

2. Foster, Gerald V., and Morris, Odell A.: Aerodynamic Characteristics in Pitch at a Mach Number of 1.97 of Two Variable-Wing-Sweep V/STOL Configurations With Outboard Wing Panels Swept Back 75°. NASA TM X-322, 1960.

3. Foster, Gerald V., and Morris, Odell A.: Static Longitudinal and Lateral Aerodynamic Characteristics at a Mach Number of 2.20 of a Variable-Wing-Sweep STOL Configuration. NASA TM X-329, 1960.

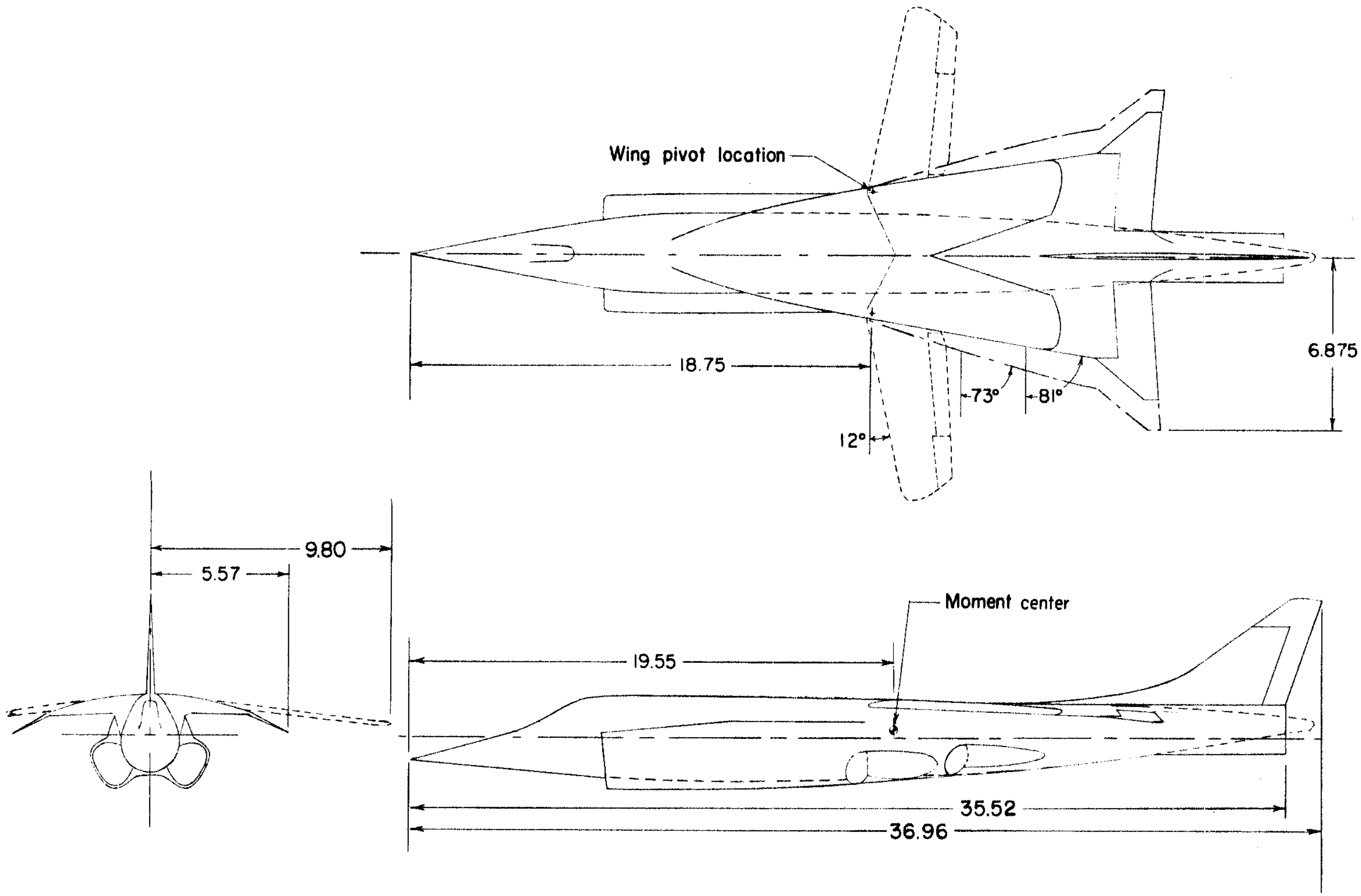
4. Morris, Odell A., and Foster, Gerald V.: Static Longitudinal and Lateral Aerodynamic Characteristics at a Mach Number of 2.20 of a V/STOL Airplane Configuration With a Variable-Sweep Wing and With a Skewed Wing Design. NASA TM X-521, 1961.

5. Luoma, Arvo A.: Longitudinal Aerodynamic Characteristics at Transonic Speeds of Two V/STOL Airplane Configurations With Skewed and Variable-Sweep Wings. NASA TM X-527, 1961.

6. Luoma, Arvo A.: Longitudinal Aerodynamic Characteristics at Transonic Speeds of a V/STOL Airplane Configuration With a Fixed Delta Wing Having Auxiliary Variable-Sweep Outboard Panels. NASA TM X-661, 1961.

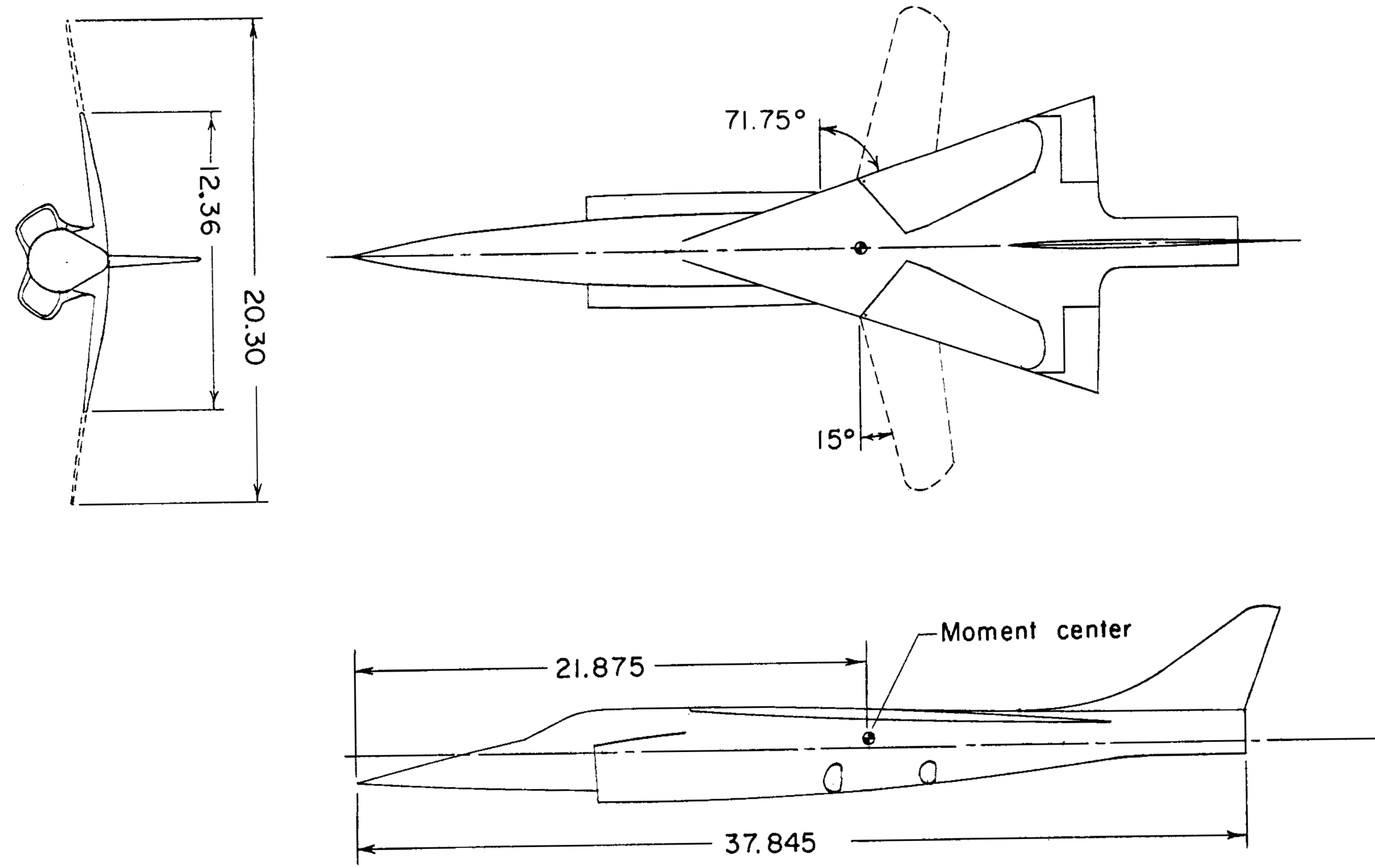
L1988

[redacted]



(a) Original configuration.

Figure 1.- Details of the models. All dimensions in inches unless otherwise noted.

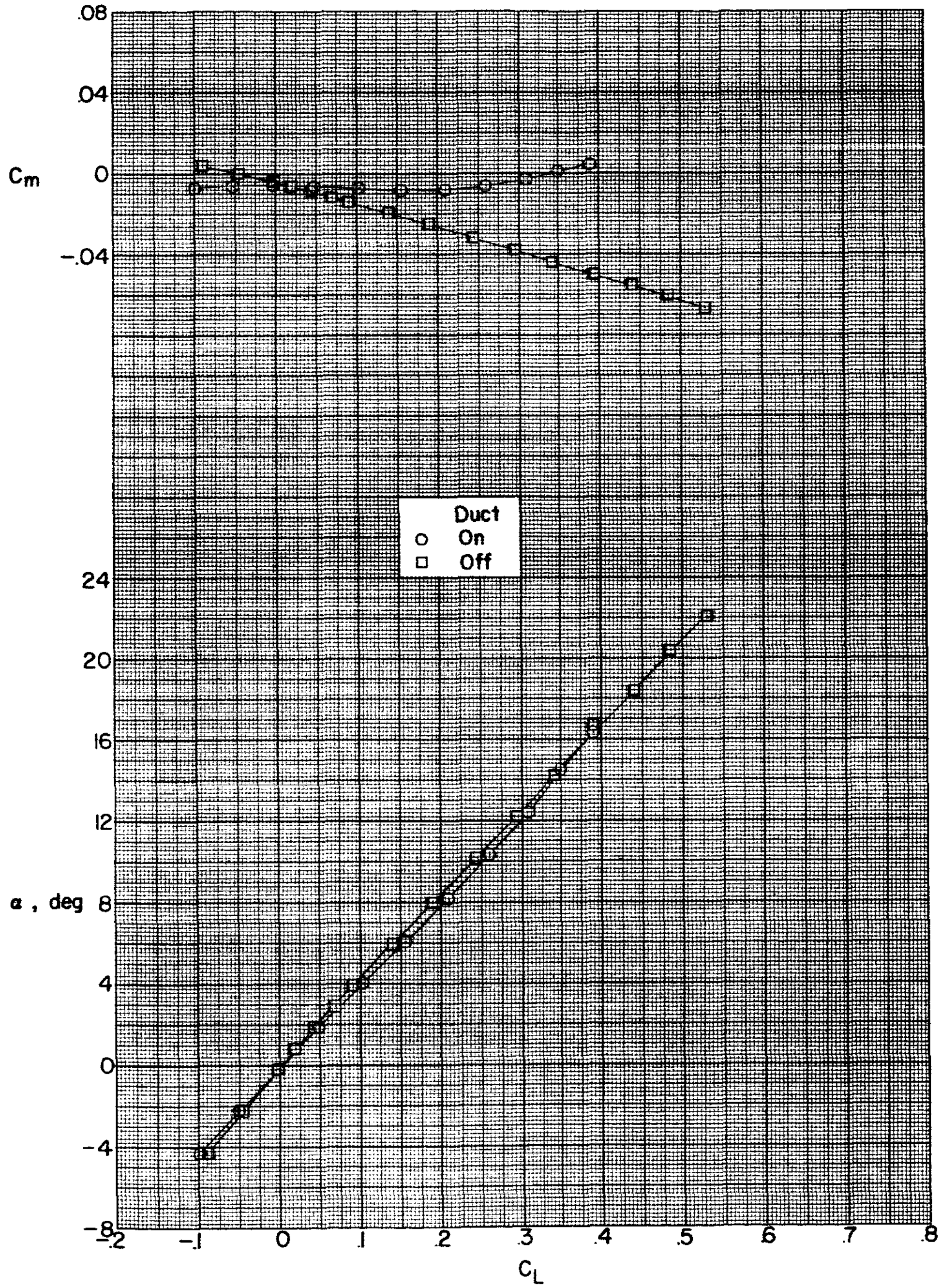


(b) Revised configuration.

Figure 1.- Concluded.

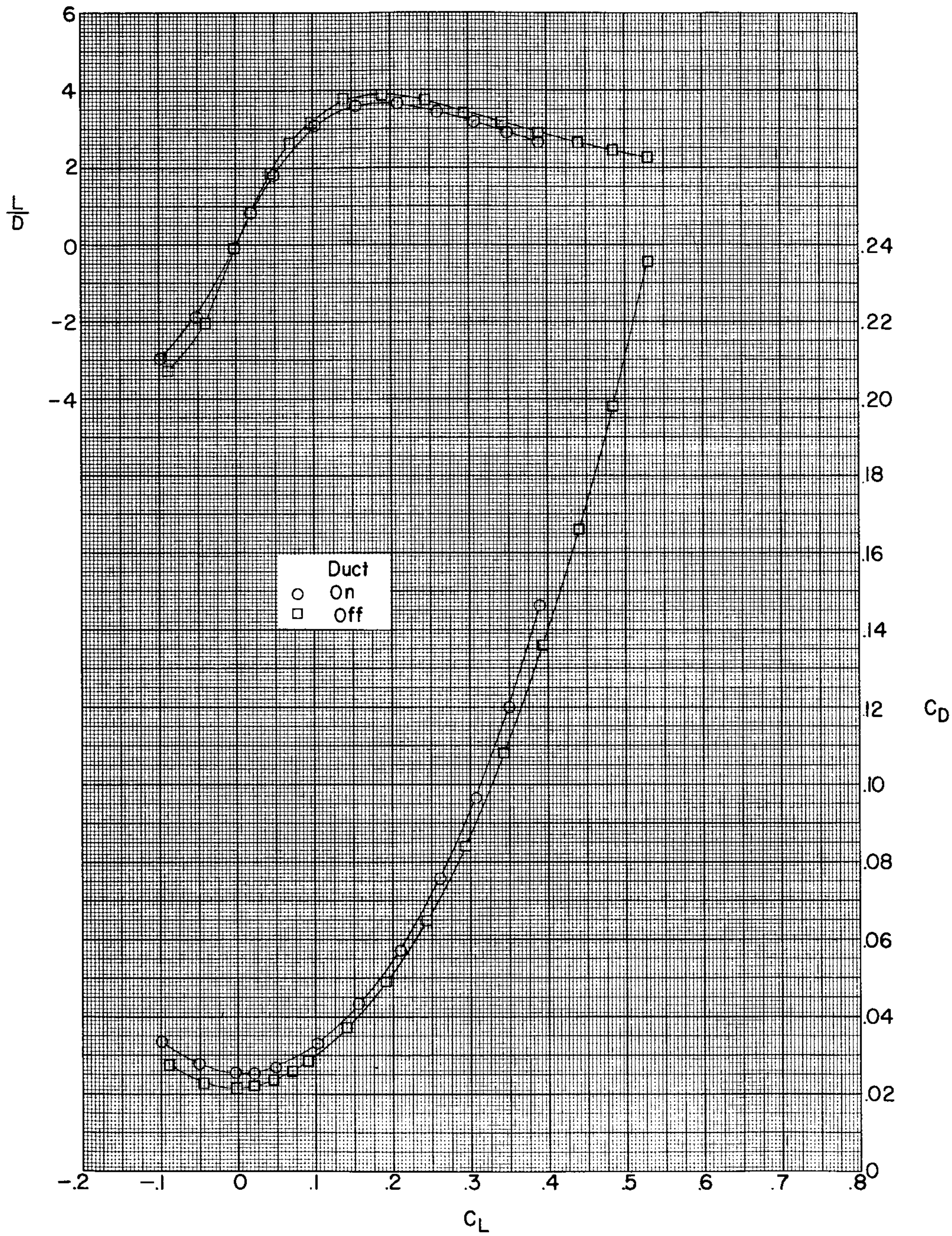
[redacted]

L-1988



(a) Variation of C_m and α with C_L.

Figure 2.- Effects of ducts on the longitudinal aerodynamic characteristics of the original configuration. $\Lambda = 81^{\circ}$.



(b) Variation of L/D and C_D with C_L.

Figure 2.- Concluded.

L-1988

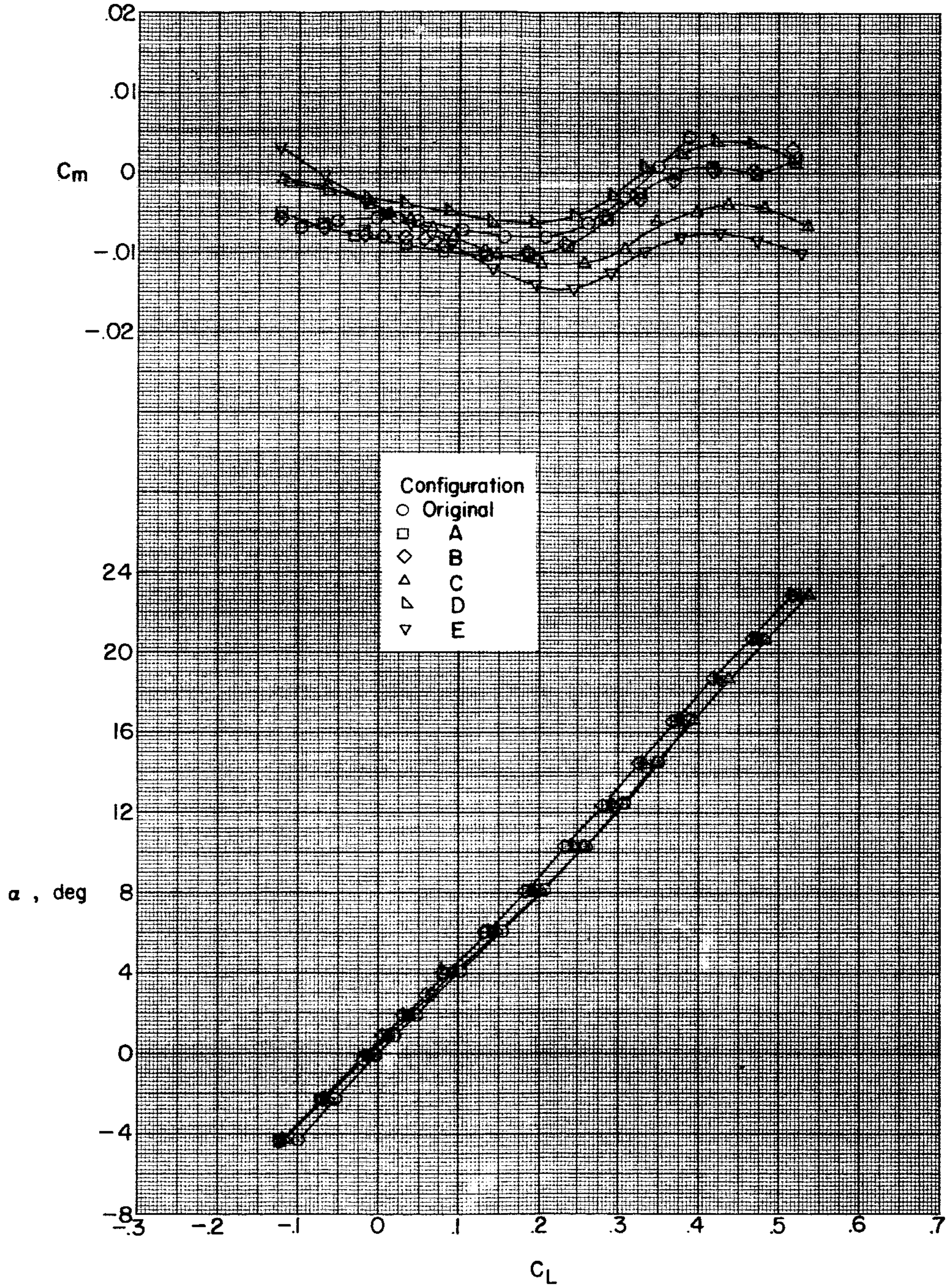
[redacted]

DECLASSIFIED

[redacted]

DECLASSIFIED

L-1988



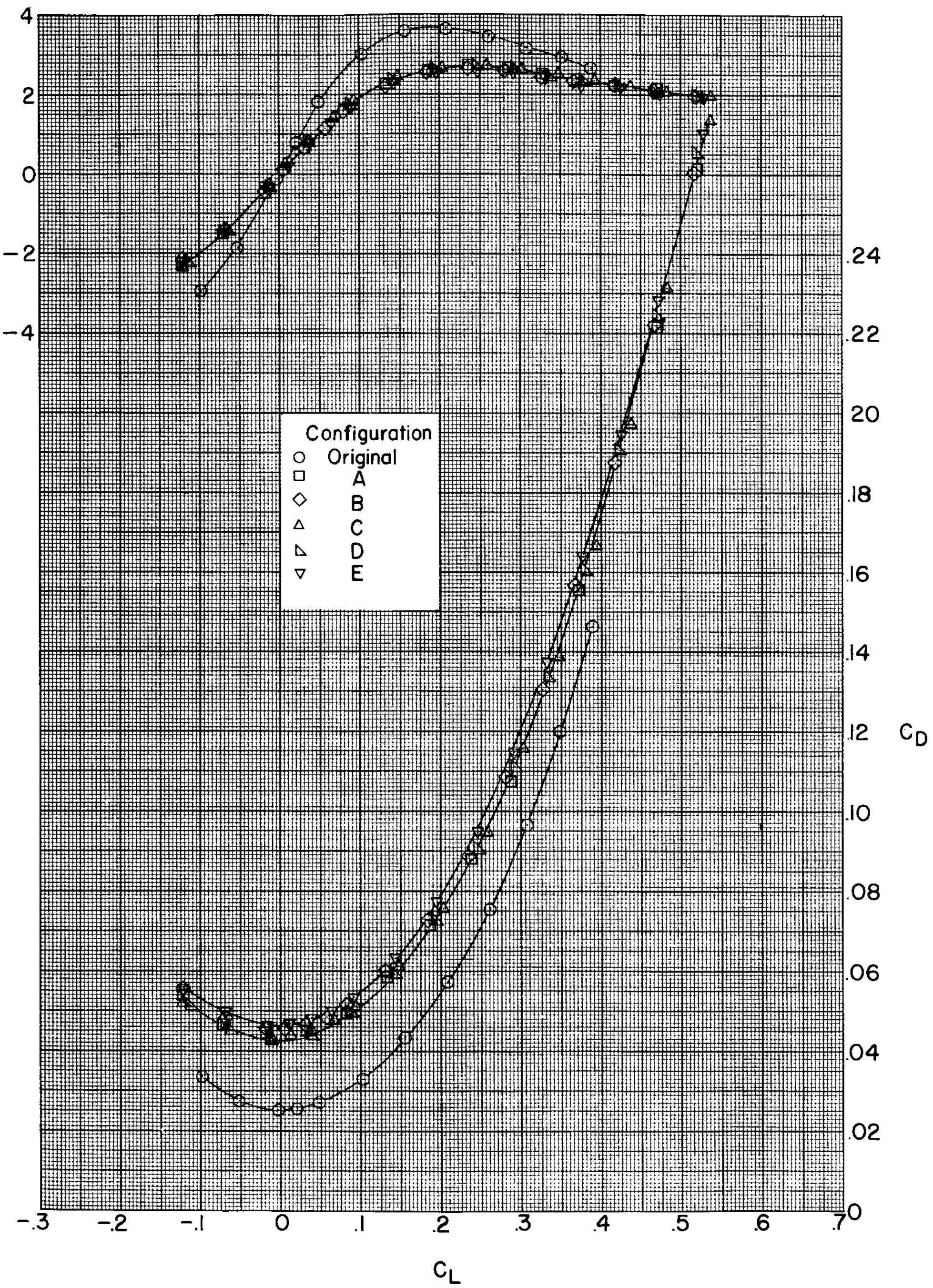
(a) Variation of C_m and α with C_L.

Figure 3.- Effects of various duct and winglet modifications on the longitudinal aerodynamic characteristics of the original configuration. $\Lambda = 81^{\circ}$.

[redacted]

[redacted]

DECLASSIFIED



(b) Variation of L/D and C_D with C_L.

Figure 3.- Concluded.

[redacted]

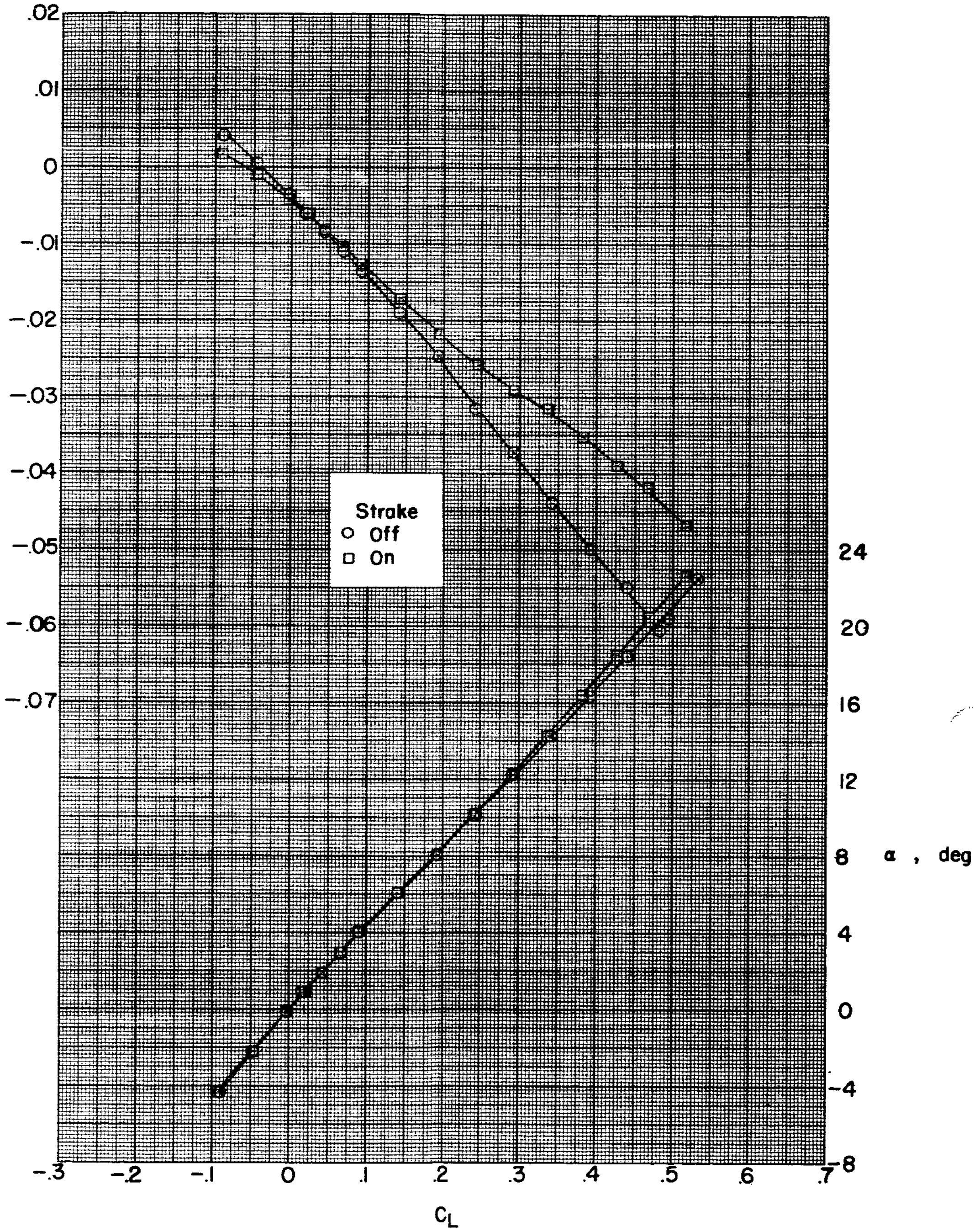
L-1988

DECLASSIFIED

[redacted]

DECLASSIFIED

L-1988



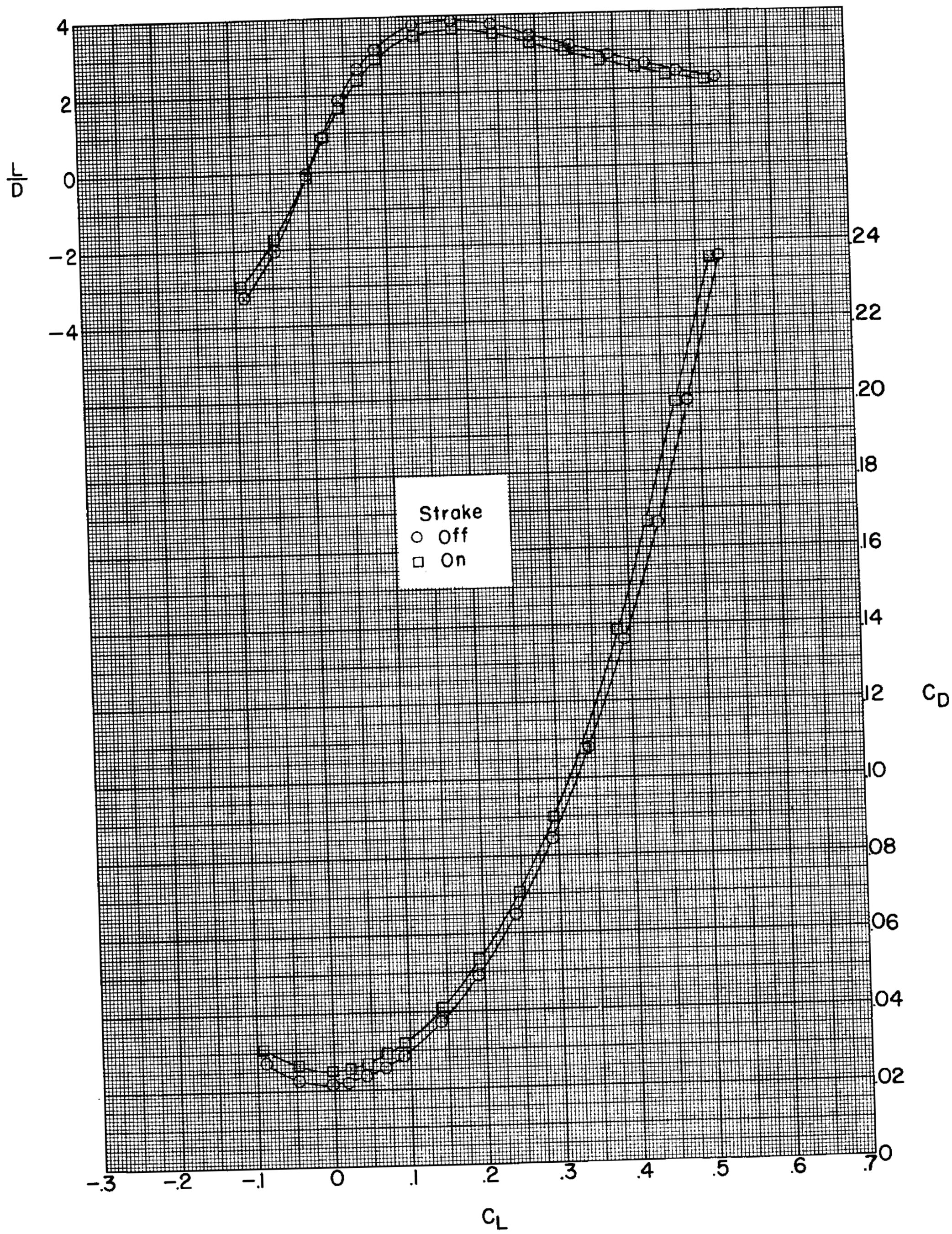
(a) Variation of C_m and α with C_L.

Figure 4.- Effects of forebody strake on the longitudinal aerodynamic characteristics of the original configuration with the ducts removed. $\Lambda = 81^{\circ}$.

[redacted]

[redacted]

DECLASSIFIED



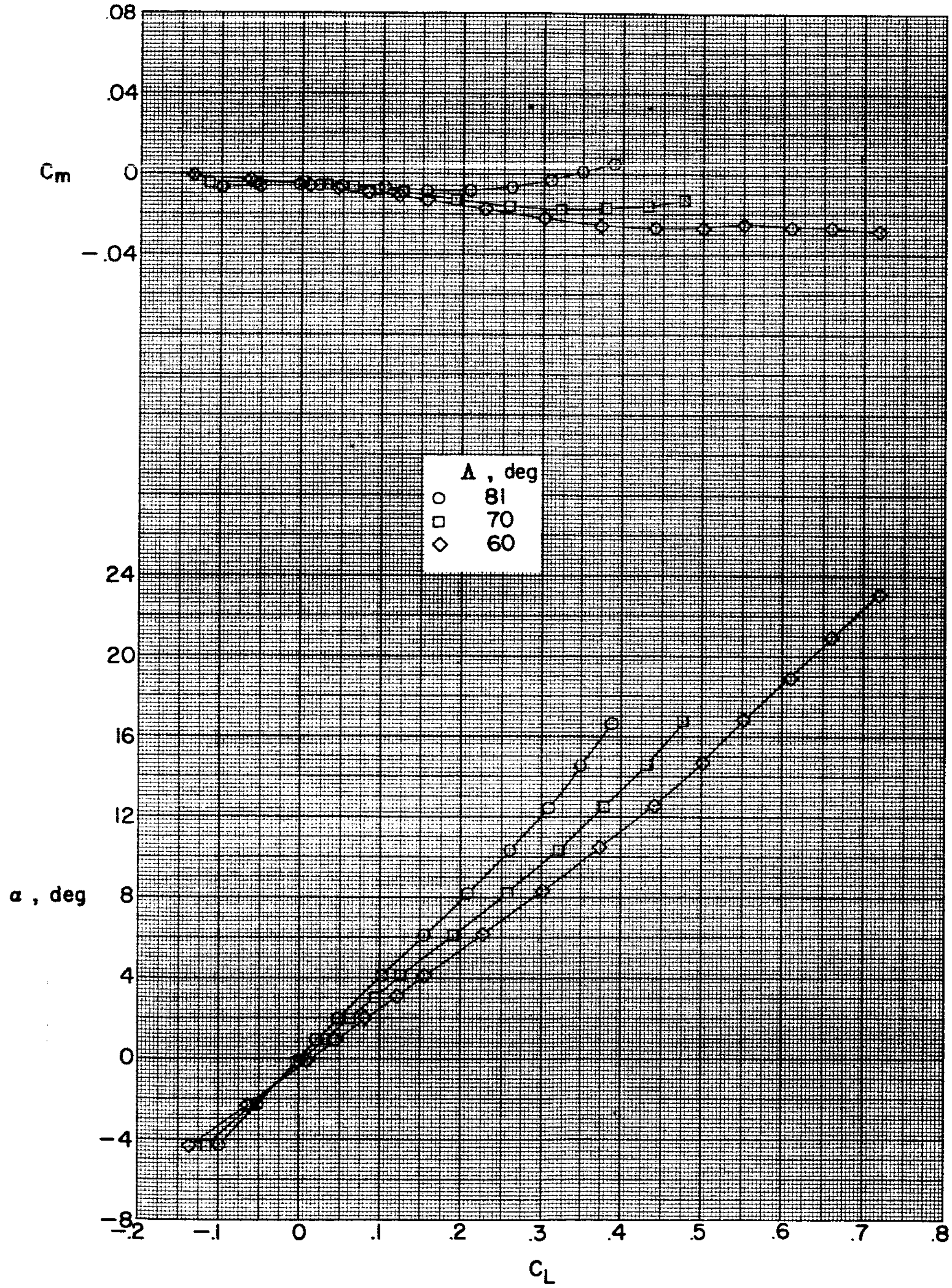
(b) Variation of L/D and C_D with C_L.

Figure 4.- Concluded.

L-1988

[redacted]

L-1988

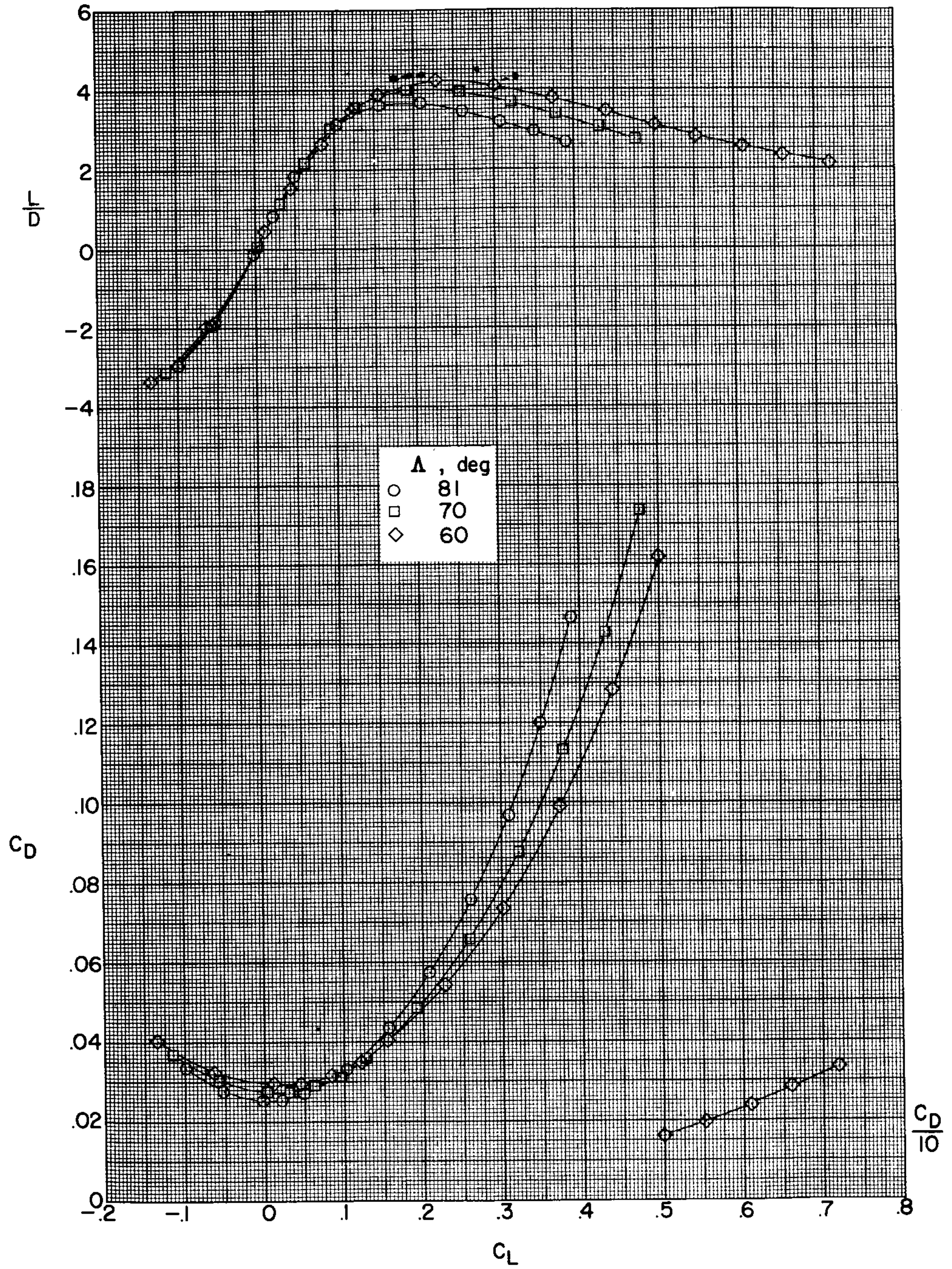


(a) Variation of C_m and α with C_L.

Figure 5.- Effects of wing sweep on the longitudinal aerodynamic characteristics of the original configuration.

[redacted]

[redacted]



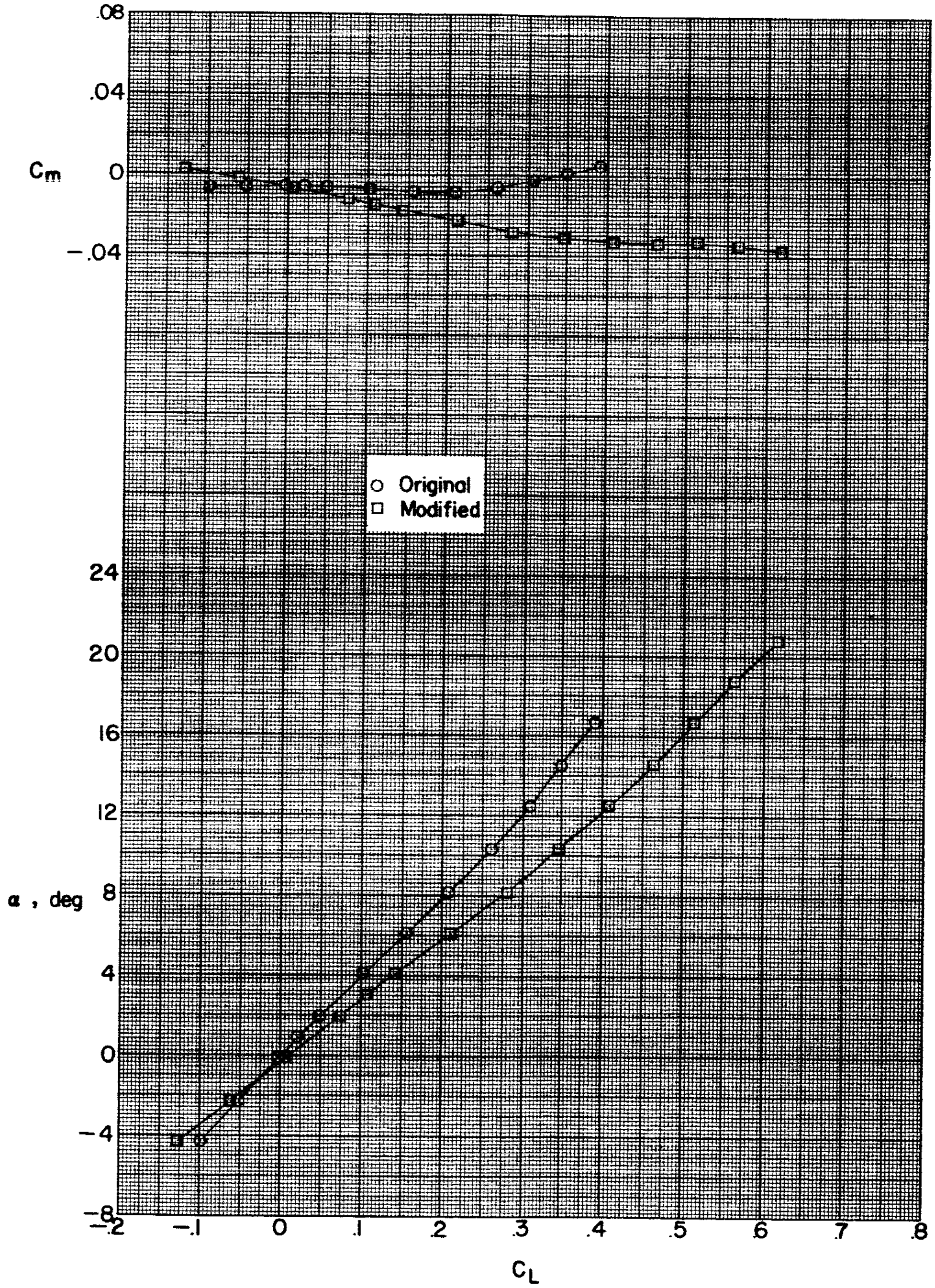
(b) Variation of L/D and C_D with C_L.

Figure 5.- Concluded.

[redacted]

L-1988

L-1988

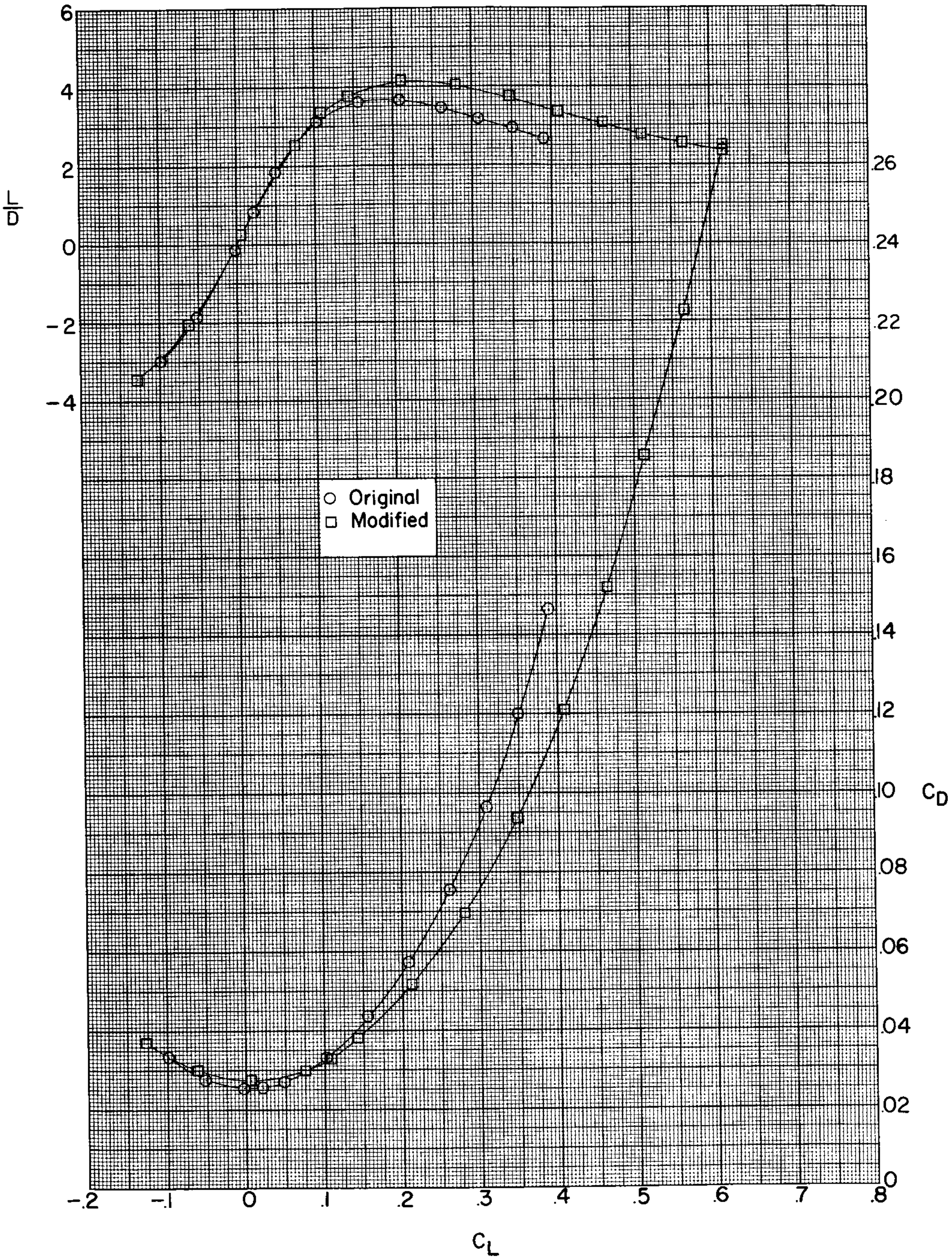


(a) Variation of C_m and α with C_L.

Figure 6.- Effects of wing planform modification on the longitudinal aerodynamic characteristics of the original configuration.

[redacted]

[redacted]



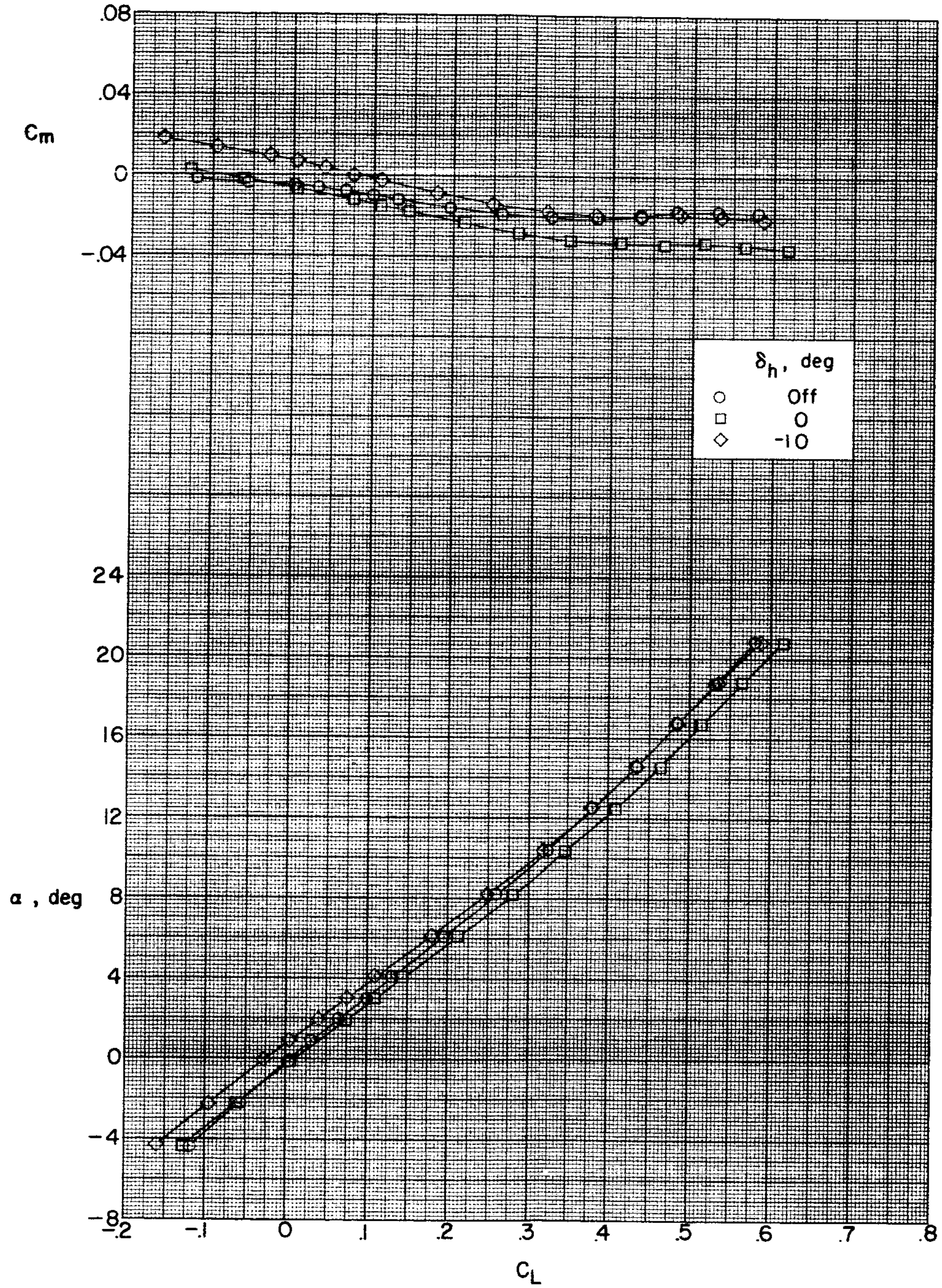
(b) Variation of L/D and C_D with C_L.

Figure 6.- Concluded.

[redacted]

L-1988

L-1988

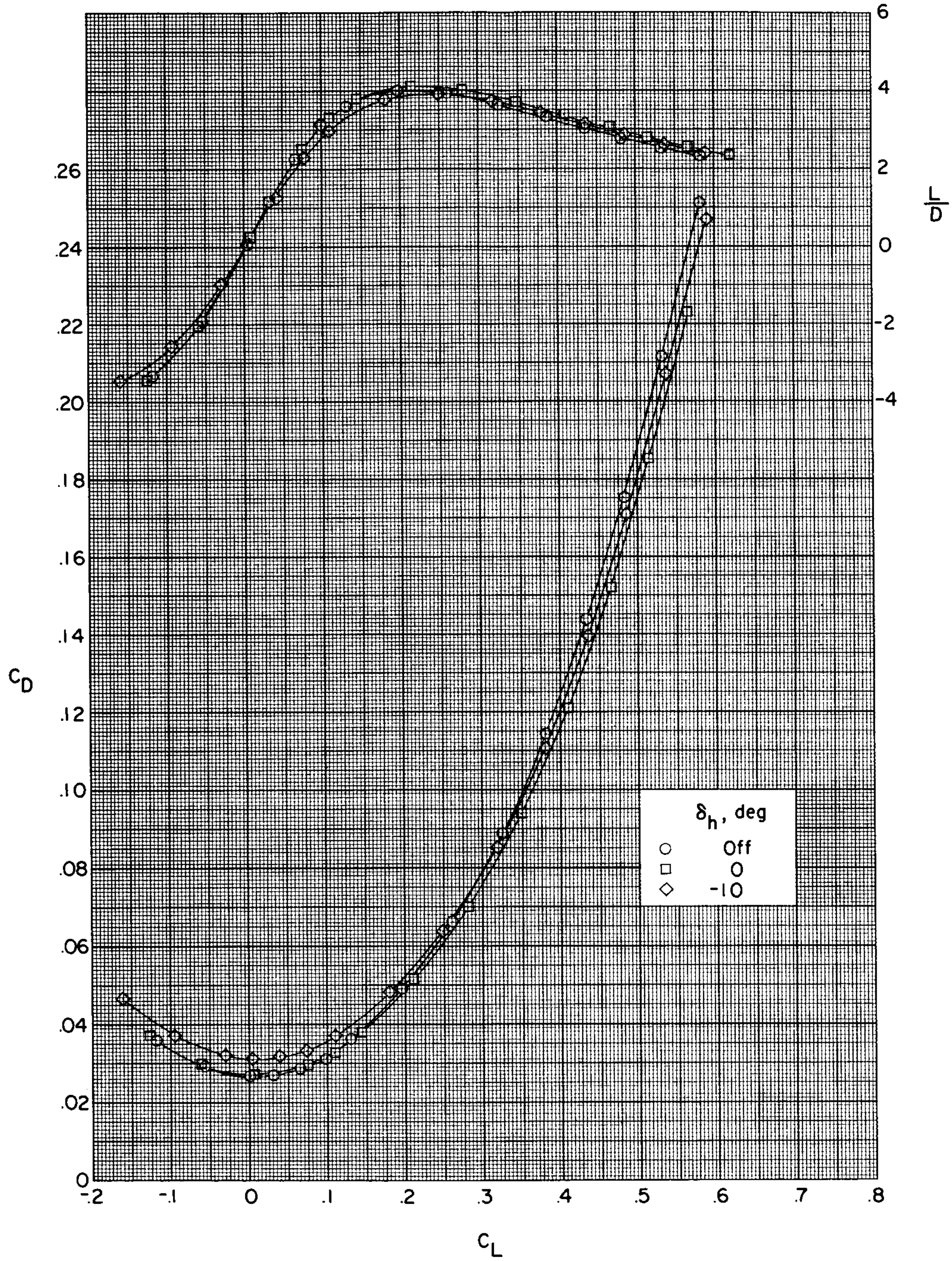


(a) Variation of C_m and α with C_L.

Figure 7.- Effects of pitch control on the longitudinal aerodynamic characteristics of the original configuration with the modified wing planform. $\Lambda = 73^{\circ}$.

[redacted]

[redacted]

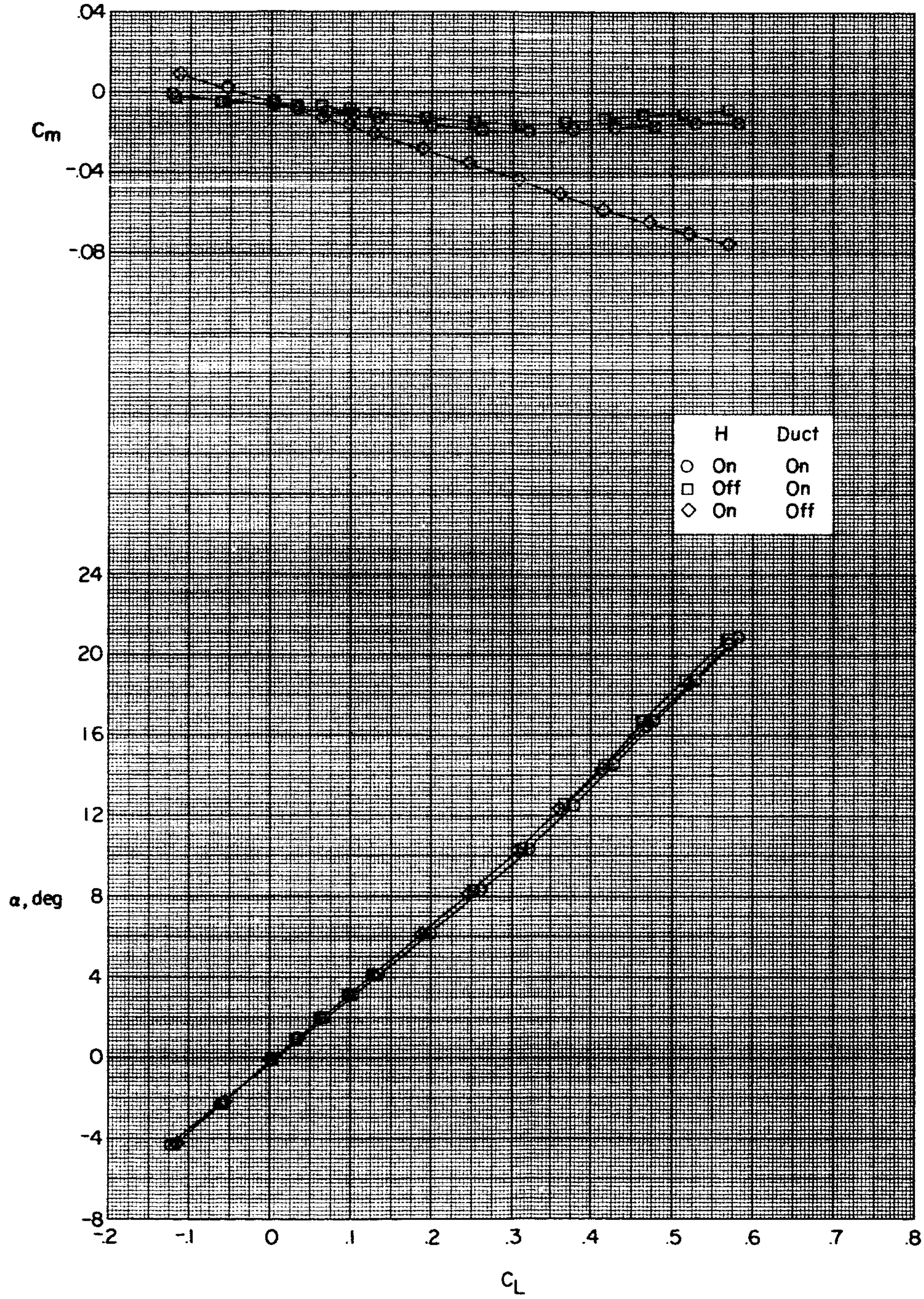


(b) Variation of L/D and C_D with C_L.

Figure 7.- Concluded.

[redacted]

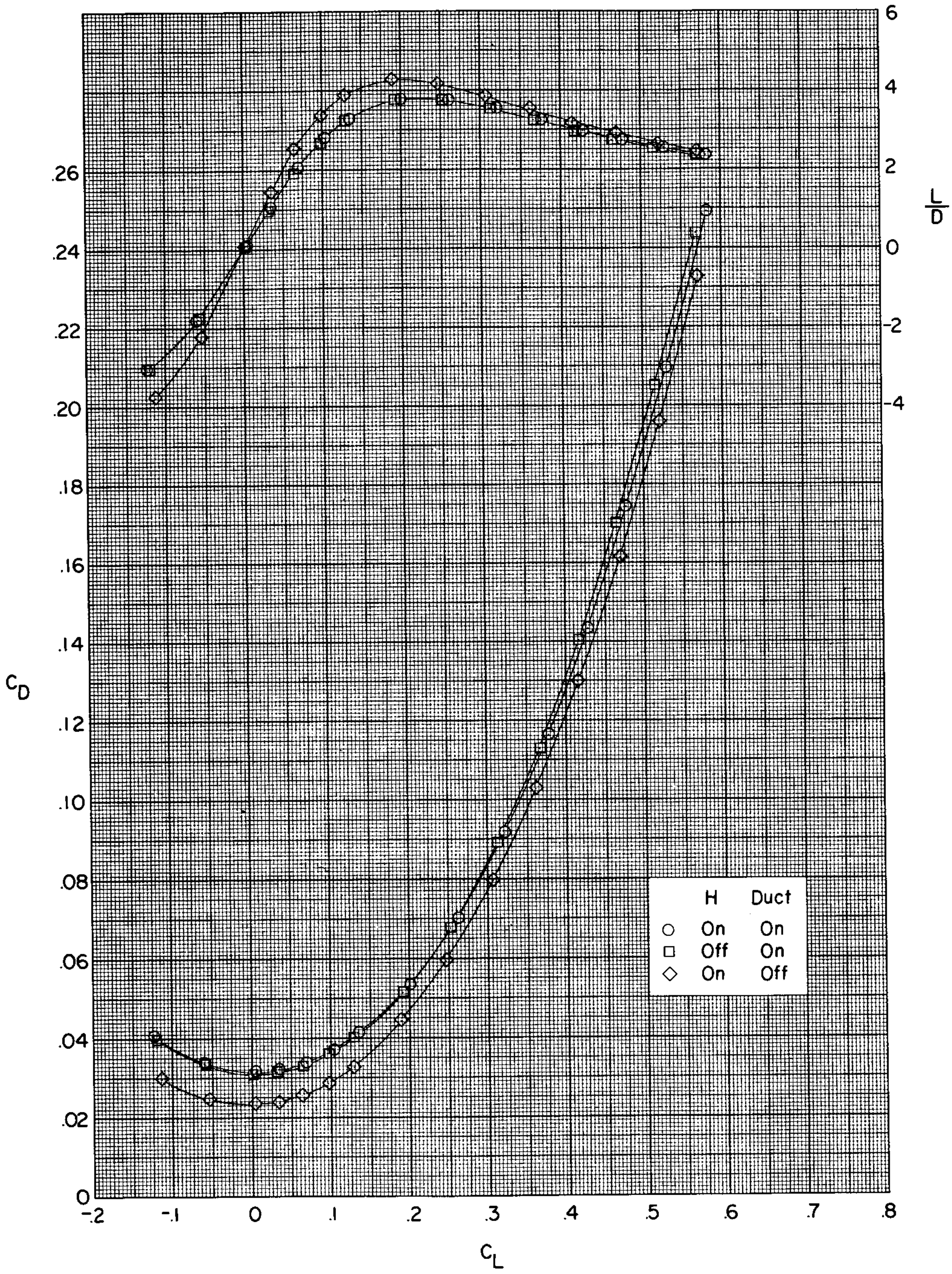
L-1988



(a) Variation of C_m and α with C_L.

Figure 8.- Effects of pitch control and ducts on the longitudinal aerodynamic characteristics of the revised configuration. $\Lambda = 71.75^{\circ}$.

[redacted]



(b) Variation of L/D and C_D with C_L.

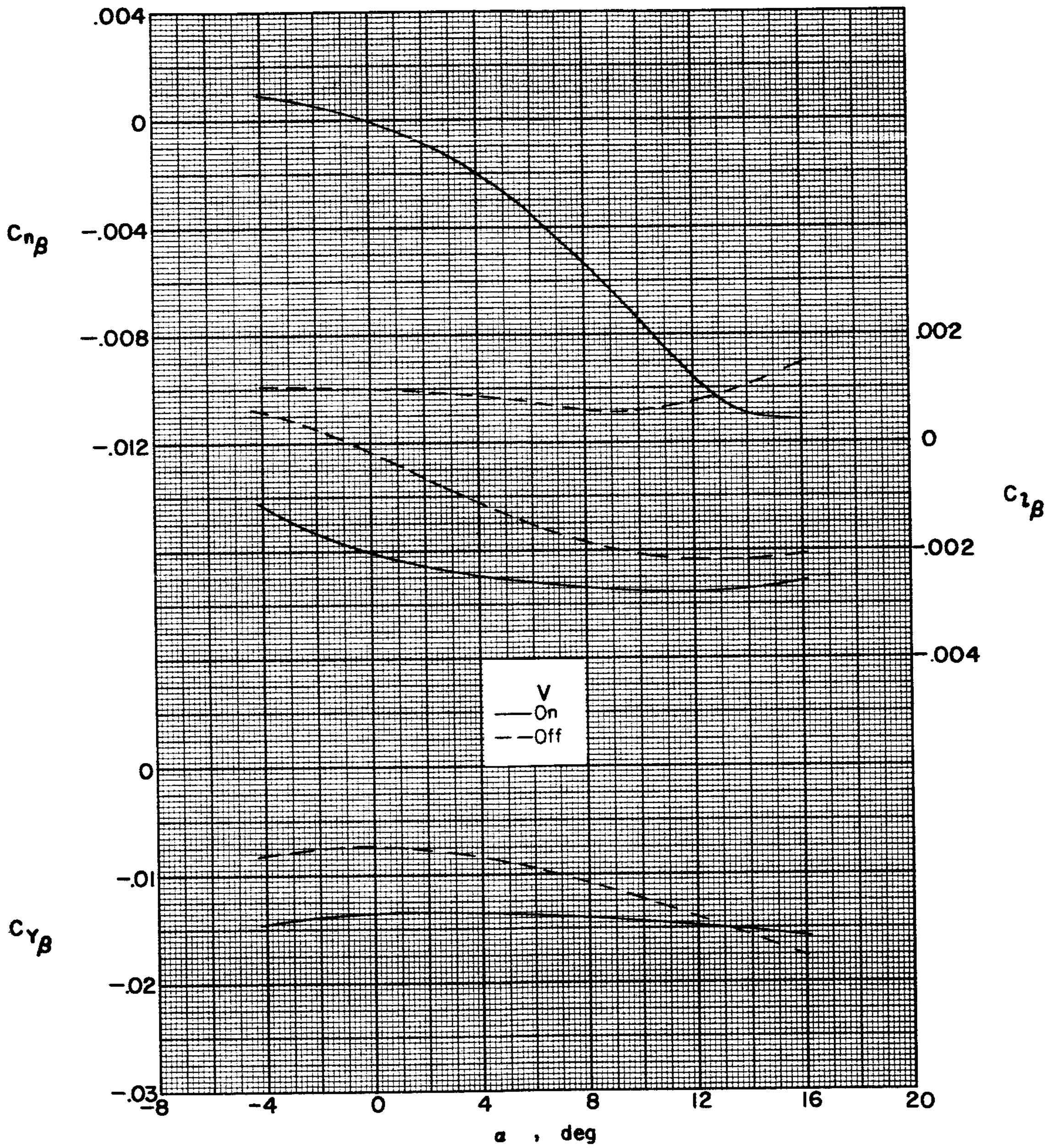
Figure 8.- Concluded.

L-1988

[redacted]

DEC[redacted]SIFIED

L-1988

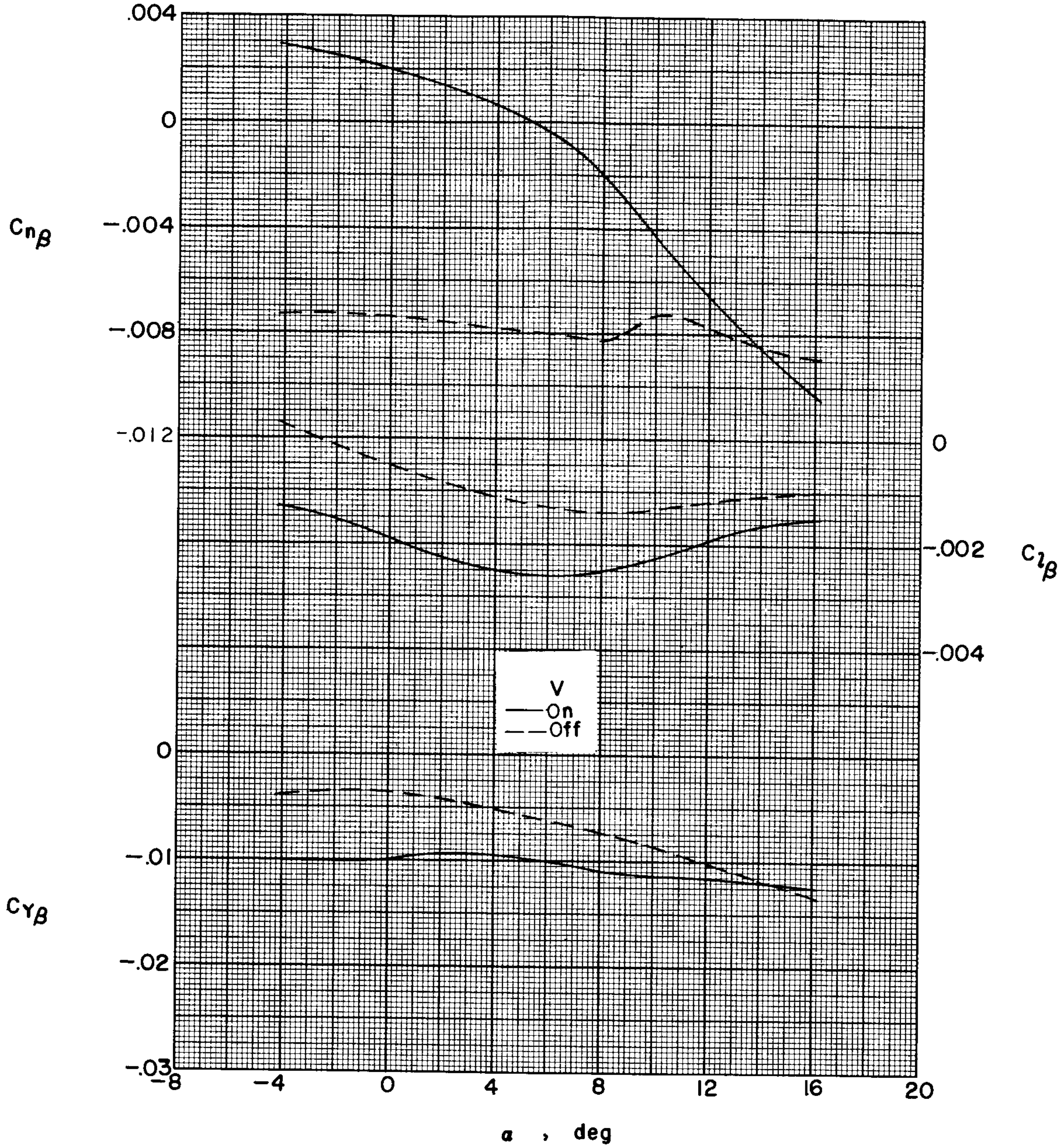


(a) Ducts on.

Figure 9.- Effects of vertical tail on the variations of sideslip derivatives with angle of attack for the original configuration. $\Lambda = 81^{\circ}$.

[redacted]

DECLASSIFIED [redacted]



(b) Ducts off.

Figure 9.- Concluded.

L-1988

[redacted]

L-1988

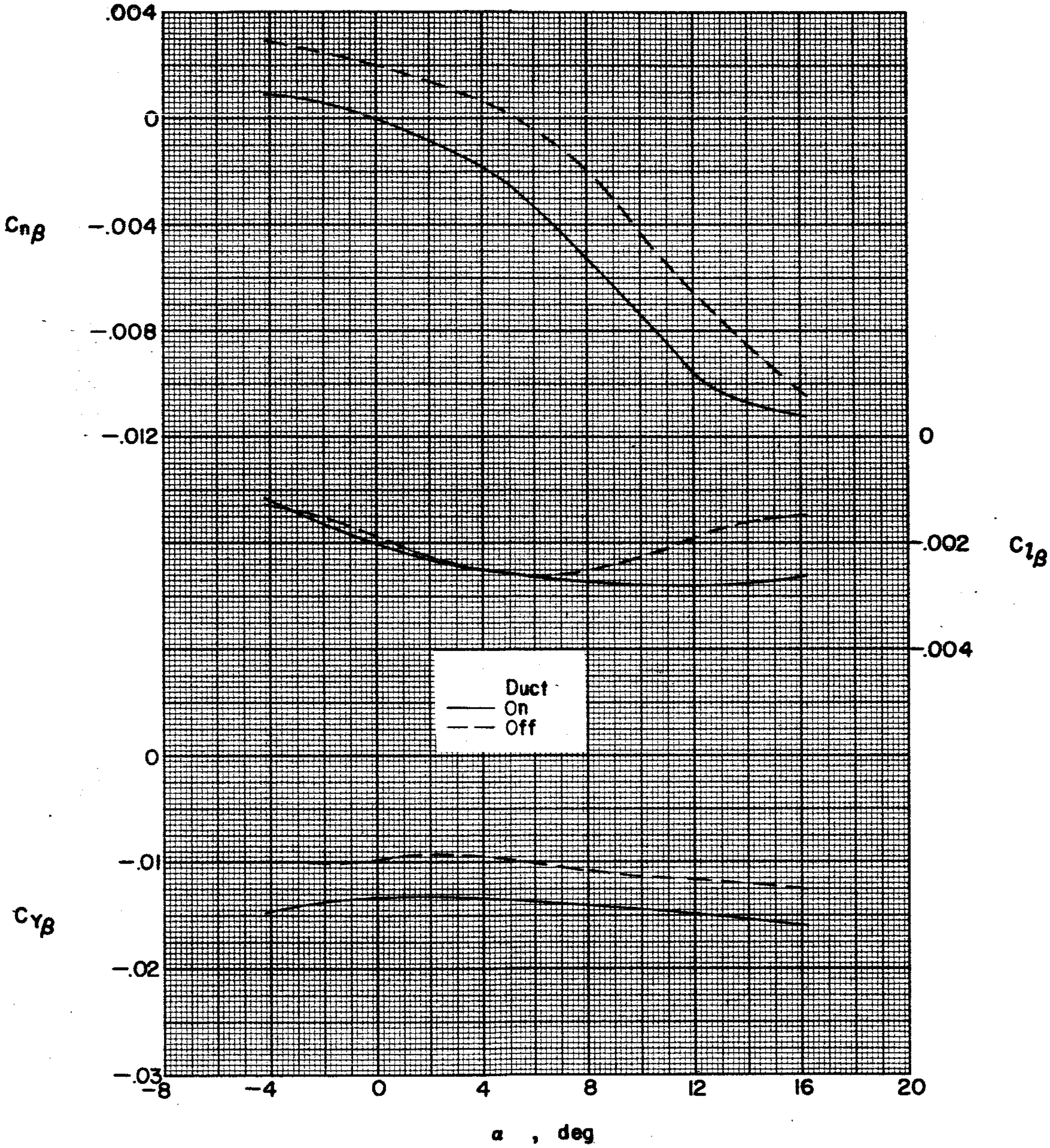


Figure 10.- Effects of ducts on the variations of sideslip derivatives with angle of attack for the original configuration. $\Lambda = 81^{\circ}$; vertical tail on.

[redacted]

L-1988

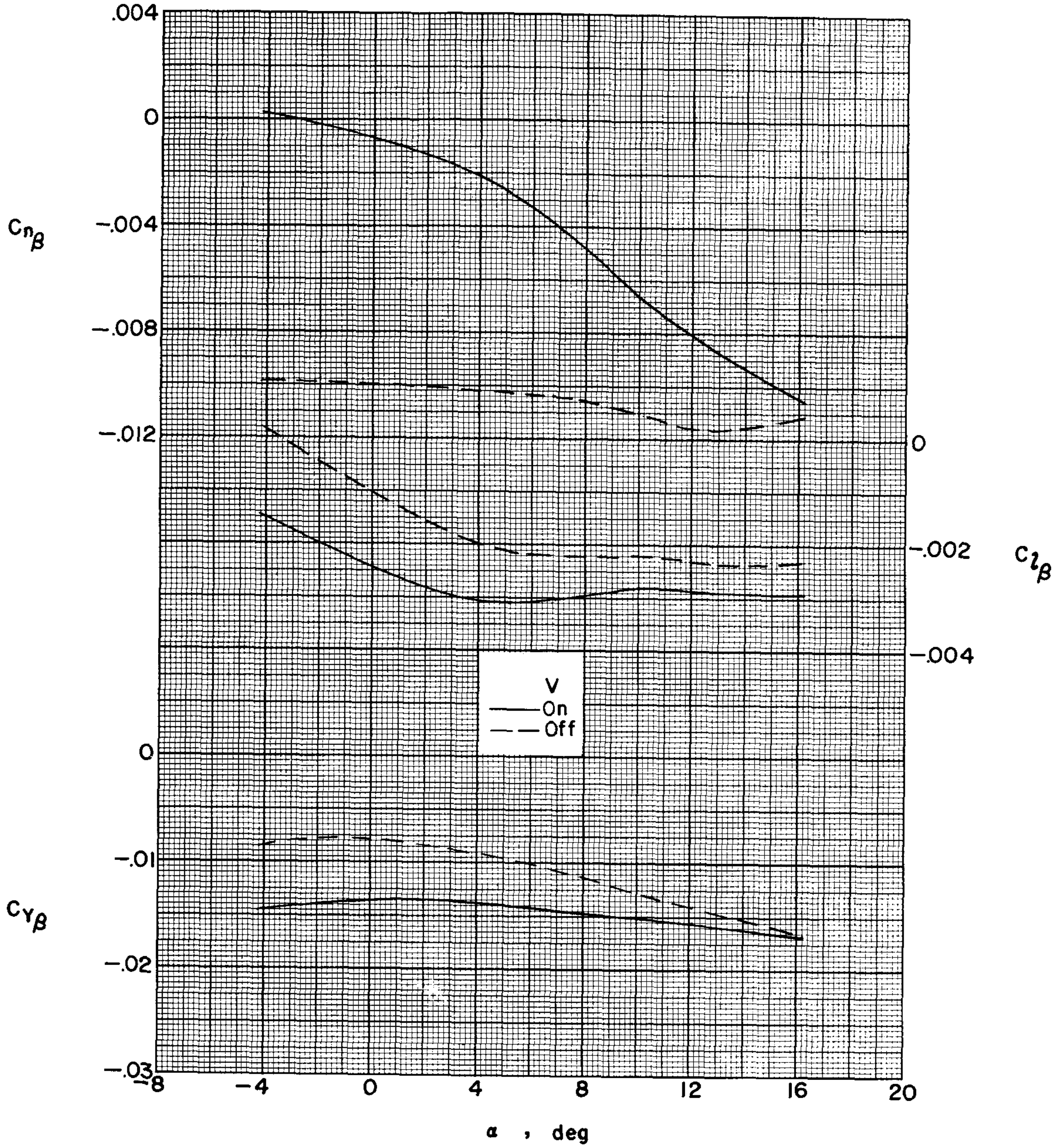


Figure 11.- Effects of vertical tail on the variations of sideslip derivatives with angle of attack for the original configuration with the modified wing planform. $\Lambda = 73^{\circ}$.

[redacted]

L-1988

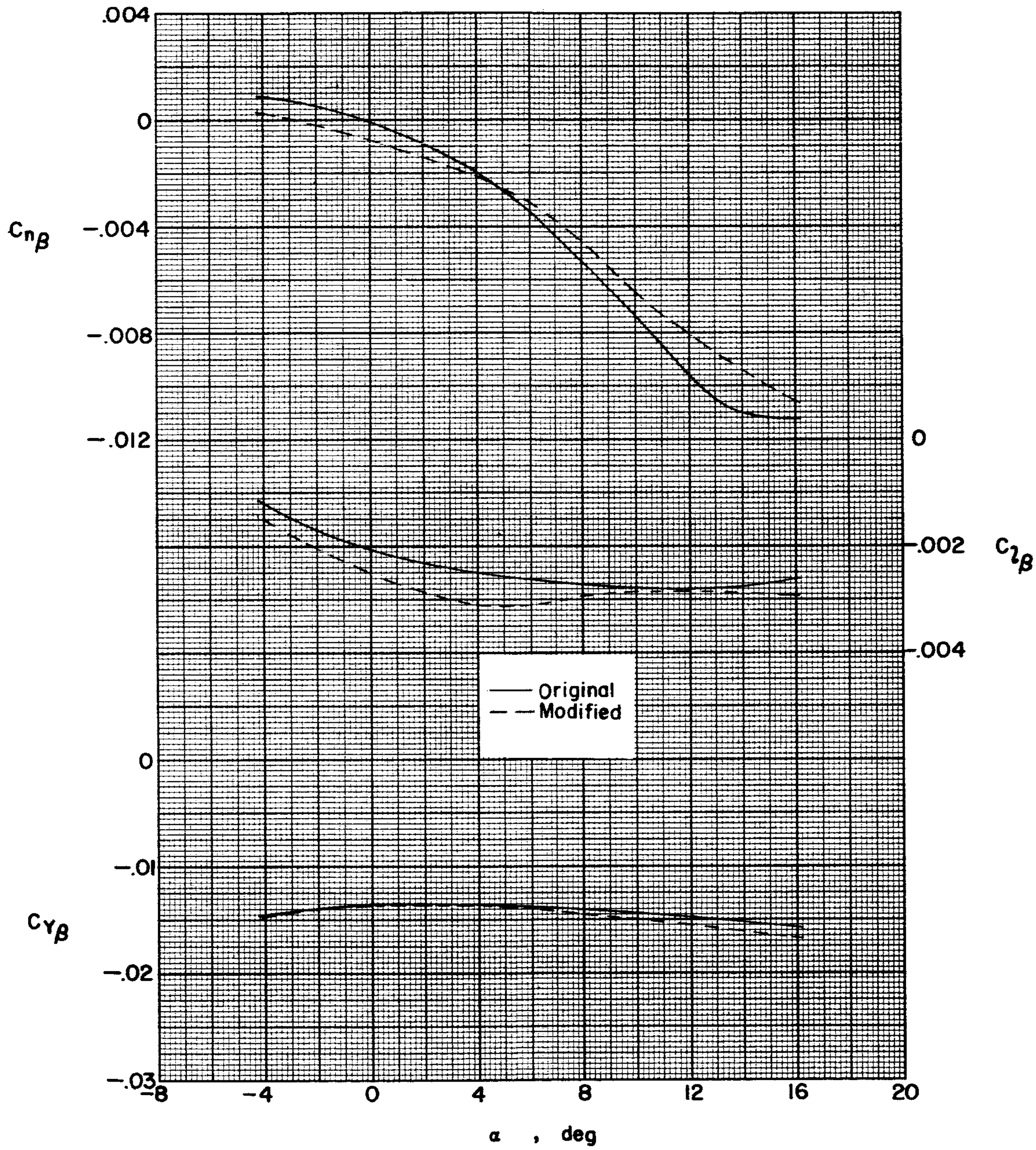


Figure 12.- Effects of wing planform modification on the variations of sideslip derivatives with angle of attack for the original configuration; vertical tail on.

[redacted]

[redacted]

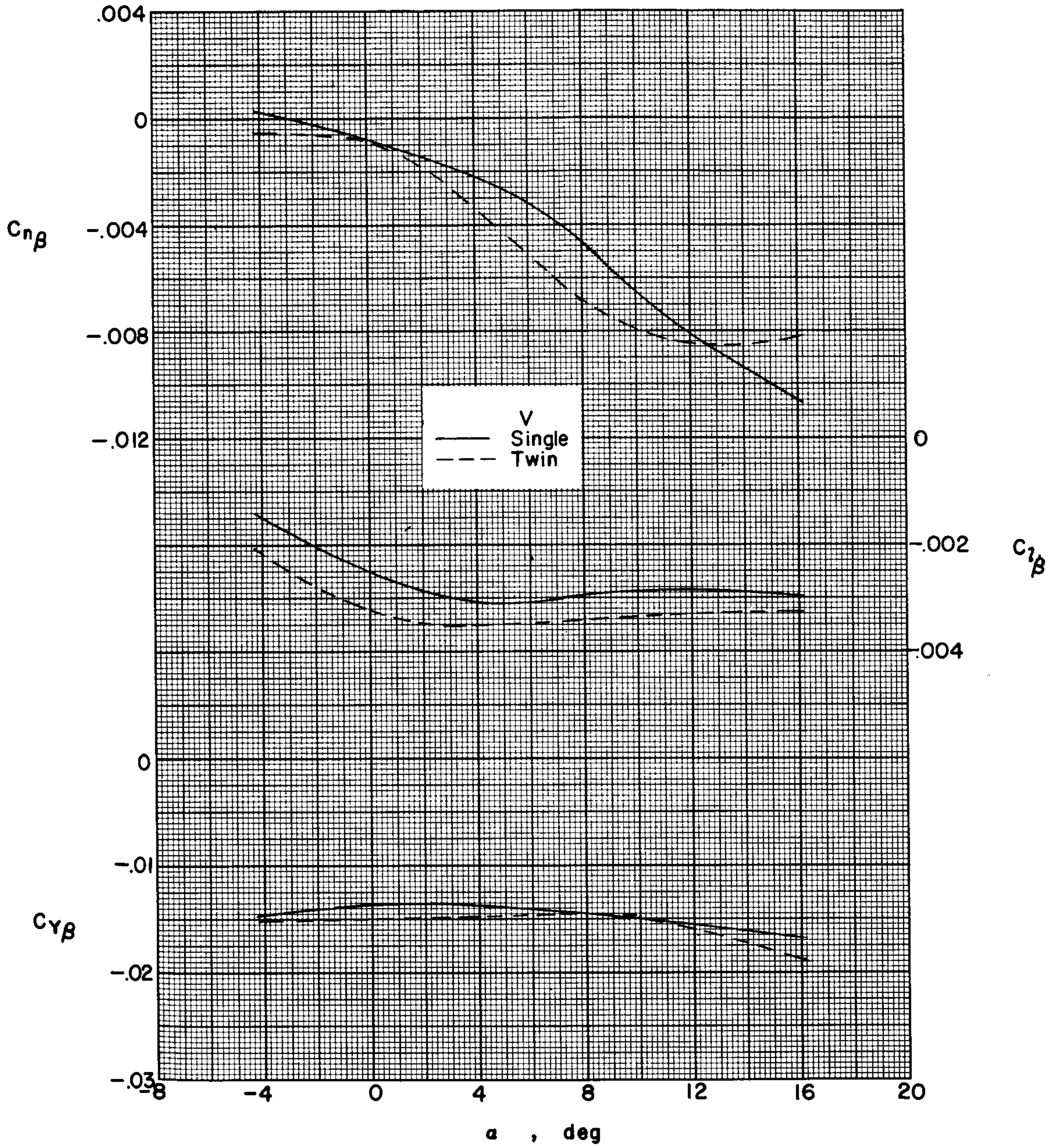


Figure 13.- Effects of twin tail arrangement on the variations of sideslip derivatives with angle of attack for the original configuration with the modified wing planform. $\Lambda = 73^{\circ}$.

L-1988

[redacted]

L-1988

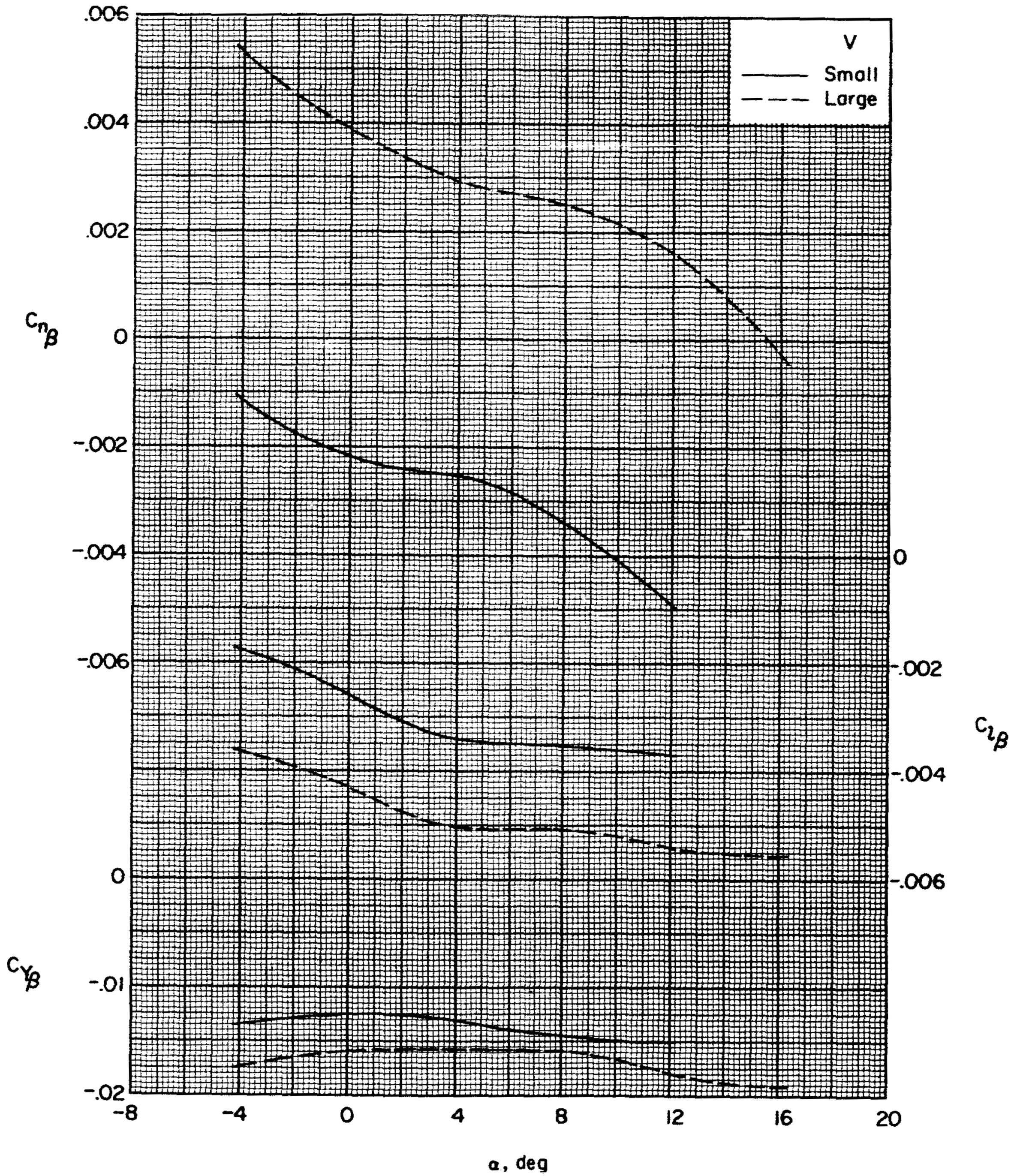


Figure 14.- Variations of sideslip derivatives with angle of attack for the revised configuration with small and large vertical tail.